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FINAL REPORT FOR NASA GRANT NAG5-2997, ANALYSIS OF DATA FROM THE TRANSIENT GAMMA-RAY SPECTROMETER EXPERIMENT ON THE GGS/WIND SPACECRAFT

The data analysis from the TGRS experiment is continuing, although the UC Berkeley PI, K. Hurley, is no longer funded for this effort. This experiment has been returning data on the energy spectra and time histories of cosmic gamma-ray bursts since November 1994, and continues to operate in good health. Over a 3 year period ending in November 1997, 41 bursts have been detected simultaneously by TGRS and Dr. Hurley's Ulysses gamma-ray burst experiment. By comparing the times of arrival of a burst at Ulysses and TGRS, we can obtain an annulus of arrival directions for the event. Typical 3σ annulus widths range from several arcminutes to tens of arcminutes. Because the WIND spacecraft is as far as several light-seconds from Earth, it is sometimes possible to obtain a second annulus using the Burst and Transient Source Experiment (BATSE) aboard the GRO spacecraft. 23 of the 41 bursts were also observed by this experiment. Generally, the two annuli intersect at grazing incidence, leading to a long, narrow error box which reduces somewhat the error circles obtained from BATSE alone. Table 1 summarizes the burst data from TGRS. We plan to defer the publication of these locations until a larger number of events has been accumulated.

Measuring the energy spectra of cosmic gamma-ray bursts to search for line emission is one of the prime objectives of this experiment. However, an intense gamma-ray burst is required, or the statistics become too weak to draw meaningful conclusions. One such event has occurred to date, on August 22, 1995, and we have examined it in detail. The spectrum shows no evidence for lines, however. The results have been reported in Seifert et al., 1997 (see Appendix 1).

A final objective has been to monitor the annihilation line from the galactic center. Results on this line have been published by Teegarden et al. (1996).

A summary of all publications in which the UC Berkeley PI has played a role appears in Appendix 1.

Table 1

THE FOLLOWING SPACECRAFT DATA HAVE BEEN EXAMINED

1.ULY -ULYSSES

2.BAT -BATSE/GRO

3.OSS -OSSE/GRO

4.COM -COMPTEL/GRO

5.EGR -EGRET/GRO

6.PVO -PIONEER VENUS ORBITER

7.GIN -GINGA - LANL EXPERIMENT

8.DMS -DEFENSE METEOR. SAT. PROGRAM

9.WAT -WATCH/GRANAT

10.SIG -SIGMA/GRANAT

11.PHE -PHEBUS/GRANAT

12.COR -CORONAS -USSR MISSION - MAZETS

13.YOH -YOHKOH

14.EUR -WATCH/EURECA

15.MO -MARS OBSERVER

16.TGR -TGRS/WIND

17.KON -KONUS/WIND

18.SAX -ITALIAN X-RAY ASTRONOMY SAT.

19.HET -HETE

20.SRS -SROSS-C

EXPLANATION OF OTHER SYMBOLS USED
NSAT-REFERS TO SPACECRAFT FOR WHICH EVENT TIME IS GIVEN
ECW, VCW, MCW, AND UCW ARE THE EARTH, VENUS, MARS,
AND ULYSSES CROSSING WINDOWS IN SECONDS
EVENT IDENT.-EVENTS ARE CATEGORIZED AS CONFIRMED
OR UNCONFIRMED COSMIC OR SOLAR, BLANK (CANDIDATE)
TRIGGERED BY COMMAND, STATISTICAL FLUCTUATION, PARTICLE-INDUCED
CONFIRMED OR UNCONFIRMED SOFT GAMMA REPEATER
CONFIRMED OR UNCONFIRMED EVENT FROM SGR1806-20, OR SGR1900+14
SYMBOLS IN SPACECRAFT COLUMNS (ULY,BAT,OSS,ETC) ARE AS FOLLOWS
YES MEANS THAT THE EXPERIMENT TRIGGERED ON THE EVENT
BLANK MEANS UNKNOWN - DATA NOT EXAMINED

RI MEANS RATE INCREASEBSERVABLE WITH THIS SPACECRAFT

NO MEANS NO TRIGGER OR RATE INCREASE, BUT THE EVENT WAS OBSERVABLE

COMMENTS REFER TO PRECEEDING LINE

DATE	DOY	TIME	T,SEC	NSAT	ECW	VCW	MCW	UCW	EVENT IDENT.	ULY	BAT	OSS	COM	EGR	PVO	GIN	DMS	WAT	SIG	PHE	COR	YOH	EUR	MO	TGR	KON	SAX	HET	SRS
1.19	NOV 94	323	19:30:50	70250	2	0	150	596	1085 CONF. COSMIC	RI	YES			N/O	N/O					N/O	N/O	YES	YES	N/O	N/O				
COMMENT.....BATSE #3287																													
2.21	NOV 94	325	17:24:57	62697	2	0	154	587	1082 CONF. COSMIC	YES	YES			N/O	N/O					N/O	N/O	YES	YES	N/O	N/O				
COMMENT.....BATSE #3290																													
3.26	NOV 94	330	12:22:01	44521	2	0	167	566	1076 CONF. COSMIC	YES	YES			N/O	N/O					N/O	N/O	YES	YES	N/O	N/O	YES			
COMMENT.....BATSE #3298																													
4. 4	JAN 95	4	07:18:39	26319	2	0	299	411	1095 CONF. COSMIC	RI	YES			N/O	N/O					N/O	N/O	YES	YES	N/O	N/O				
COMMENT.....BATSE #3345																													
5.11	JAN 95	11	12:18:30	44310	2	0	326	388	1106 CONF. COSMIC	RI	YES			N/O	N/O					N/O	N/O	RI	YES	N/O	N/O				
COMMENT.....BATSE #3352																													
6.14	JAN 95	14	13:10:35	47435	16	0	337	380	1111 CONF. COSMIC	YES	NO			N/O	N/O					N/O	N/O	YES	YES	N/O	N/O				
7. 7	APR 95	97	15:15:32	54932	16	0	632	471	1114 CONF. COSMIC	YES	NO			N/O	N/O	YES				YES	N/O	N/O	YES	YES	N/O	N/O	YES		
8. 4	AUG 95	216	01:58:54	7134	2	0	860	935	1137 CONF. COSMIC	YES	YES			N/O	N/O	YES				YES	N/O	N/O	YES	YES	N/O	N/O			
COMMENT.....BATSE #3734																													
9. 5	AUG 95	217	03:44:14	13454	2	0	860	937	1141 CONF. COSMIC	RI	YES			N/O	N/O					N/O	N/O	YES	YES	N/O	N/O				
COMMENT.....BATSE #3736																													
10. 9	AUG 95	221	23:52:25	85945	2	0	861	949	1157 CONF. COSMIC	RI	YES			N/O	N/O					N/O	N/O	YES	YES	N/O	N/O				
COMMENT.....BATSE #3750																													
11.18	AUG 95	230	01:23:22	5002	2	0	862	973	1194 CONF. COSMIC	YES	YES			N/O	N/O					N/O	N/O	YES	YES	N/O	N/O				
COMMENT.....BATSE #3765																													
12.22	AUG 95	234	03:49:09	13749	2	0	862	984	1210 CONF. COSMIC	YES	YES			N/O	N/O					YES	N/O	N/O	YES	YES	N/O	N/O			
COMMENT.....BATSE #3767																													
13.14	OCT 95	287	03:38:28	13108	17	0	821	1089	1387 CONF. COSMIC	YES	NO			N/O	N/O	NO				N/O	N/O	YES	YES	N/O	N/O				
14.13	NOV 95	317	23:25:56	84356	2	0	771	1126	1424 CONF. COSMIC	RI	YES			N/O	N/O					N/O	N/O	RI	YES	N/O	N/O				
COMMENT.....BATSE #3906																													
15.19	NOV 95	323	08:17:12	29832	2	0	759	1132	1425 CONF. COSMIC	RI	YES			N/O	N/O					N/O	N/O	YES	YES	N/O	N/O				
COMMENT.....BATSE #3912																													

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  16.19 NOV 95 323 12:54:17 46457  17     0  759 1132 1425 CONF. COSMIC   RI  NO          N/O N/O                  N/O N/O RI  YES N/O N/O
□
  17.22 NOV 95 326 04:45:07 17107  17     0  753 1135 1425 CONF. COSMIC   RI  NO          N/O N/O                  N/O N/O YES YES N/O N/O
  18. 2 DEC 95 336 10:51:40 39100   2     0  731 1143 1423 CONF. COSMIC   RI  YES         N/O N/O                  N/O N/O RI  YES N/O N/O
COMMENT.....BATSE #3929
  19. 3 DEC 95 337 01:06:28  3988   2     0  729 1144 1423 CONF. COSMIC   YES YES         N/O N/O                  N/O N/O YES YES N/O N/O
COMMENT.....BATSE #3930
  20. 8 DEC 95 342 11:47:23 42443   2     0  718 1147 1421 CONF. COSMIC   RI  YES         N/O N/O                  N/O N/O RI  YES N/O N/O
COMMENT.....BATSE #3937
  21.13 DEC 95 347 04:57:32 17852   2     0  706 1151 1418 CONF. COSMIC   RI  YES         N/O N/O                  YES N/O N/O YES YES N/O N/O
COMMENT.....BATSE #3954
  22.20 DEC 95 354 08:51:21 31881   2     0  689 1155 1413 CONF. COSMIC   RI  YES         N/O N/O                  N/O N/O RI  YES N/O N/O
□
COMMENT.....BATSE #4048
  23.27 DEC 95 361 06:23:25 23005  17     0  671 1159 1408 CONF. COSMIC   YES NO          N/O N/O NO               N/O N/O YES YES N/O N/O
□
  24.14 JAN 96  14 12:15:04 44104   2     0  621 1168 1399 CONF. COSMIC   YES YES         N/O N/O                  N/O N/O YES YES N/O N/O YES
COMMENT.....BATSE #4368 ALSO OBSERVED BY KONUS-A
  25.24 JAN 96  24 00:56:26  3386   2     0  592 1172 1399 CONF. COSMIC   YES YES         N/O N/O                  N/O N/O YES YES N/O N/O
COMMENT.....BATSE #4556 ALSO OBSERVED BY KONUS-A
  26.24 SEP 96 268 11:41:50 42110   2     0  484  991 2565 CONF. COSMIC   YES YES         N/O N/O                  N/O N/O YES YES      N/O
□
COMMENT.....BATSE #5614
  27.17 JAN 97  17 14:46:51 53211  16     0  792  503 2037 CONF. COSMIC   YES NO          N/O N/O NO               N/O N/O YES NO  YES N/O
□
  28.24 JAN 97  24 12:50:53 46253  16     0  803  472 2011 CONF. COSMIC   YES NO          N/O N/O NO               N/O N/O YES YES      N/O
  29.11 APR 97 101 09:52:36 35556  16     0  860  351 2204 CONF. COSMIC   YES YES         N/O N/O NO               N/O N/O YES YES      N/O
COMMENT.....BATSE #6168
  30. 6 MAY 97 126 15:41:43 56503   2     0  848  421 2414 CONF. COSMIC   YES NO          N/O N/O NO               N/O N/O YES YES      N/O
  31. 2 JUN 97 153 16:20:56 58856  17     0  817  518 2653 CONF. COSMIC   YES NO          N/O N/O YES              N/O N/O YES YES      N/O
  32.25 JUN 97 176 12:13:15 43995  16     0  774  603 2837 CONF. COSMIC   YES NO          N/O N/O RI               N/O N/O YES YES      N/O NO
  33.27 JUN 97 178 22:06:49 79609  17     0  769  611 2852 CONF. COSMIC   YES NO          N/O N/O NO               N/O N/O YES YES YES N/O
  34.15 JUL 97 196 14:21:34 51694   8     0  725  674 2966 CONF. COSMIC   YES NO          N/O N/O YES              N/O N/O YES YES      N/O YES
  35.21 JUL 97 202 23:31:12 84672   8     0  709  694 2998 CONF. COSMIC   YES NO          N/O N/O YES              N/O N/O YES YES      N/O
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36.15	SEP 97	258	09:07:51	32871	17	0	527	856	3101	CONF. COSMIC	YES NO	N/O N/O RI	N/O N/O YES YES	N/O
37.19	SEP 97	262	18:14:29	65669	2	0	513	865	3094	CONF. COSMIC	YES YES	N/O N/O NO	N/O N/O YES YES	N/O
COMMENT.....BATSE #6389														
38.21	SEP 97	264	23:25:22	84322	16	0	505	870	3090	CONF. COSMIC	YES NO	N/O N/O	N/O N/O YES YES	N/O
39.23	SEP 97	266	11:39:21	41961	16	0	498	875	3085	CONF. COSMIC	YES NO	N/O N/O	N/O N/O YES YES	N/O
40.25	SEP 97	268	22:43:15	81795	2	0	491	880	3080	CONF. COSMIC	RI YES	N/O N/O RI	N/O N/O YES YES	N/O
COMMENT.....BATSE #6397														
41.19	OCT 97	292	14:55:54	53754	17	0	401	932	2984	CONF. COSMIC	YES NO	N/O N/O RI	N/O N/O YES YES	N/O

APPENDIX 1

Publications Resulting from NASA grant NAG5-2997
WIND Transient Gamma-Ray Spectrometer

K. Hurley, Principal Investigator

1995

Status of the transient gamma-ray spectrometer, H. Seifert, B.J. Teegarden, D. Palmer, N. Gehrels, T.L. Cline, R. Ramaty, A. Owens, K. Hurley, R. Pehl, and N. Madden, *Astrophys. Space Sci.* **231**, 475, 1995.

1996

TGRS observation of the galactic center annihilation line, B.J. Teegarden, T.L. Cline, N. Gehrels, D. Palmer, R. Ramaty, H. Seifert, K. Hurley, D.A. Landis, N.W. Madden, D. Malone, R. Pehl, and A. Owens, *Astrophys. J.* **463**, L75, 1996.

TGRS occultation analysis of the galactic center region, B.J. Teegarden, T. L. Cline, N. Gehrels, K.C. Hurley, A. Owens, D. Palmer, R. Ramaty, and H. Seifert, *Astron. Astrophys. Suppl. Ser.* **120**, 283, 1996.

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1997

TGRS results on the spatial and temporal behavior of the galactic center 511 keV line, B.J. Teegarden, T.L. Cline, N. Gehrels, R. Ramaty, H. Seifert, M. Harris, D. Palmer, K. Hurley, *Proc. 4th Compton Symp.*, 1007, 1997.

Transient Gamma-Ray Spectrometer observation of the bright gamma-ray burst GRB 950822, H. Seifert, B.J. Teegarden, T. L. Cline, N. Gehrels, J. J. M. In T'Zand, D. M. Palmer, R. Ramaty, K. Hurley, N. W. Madden, and R. Pehl, *Astrophys. J.*,.**491**, #2, 697, 20 Dec. 1997.